

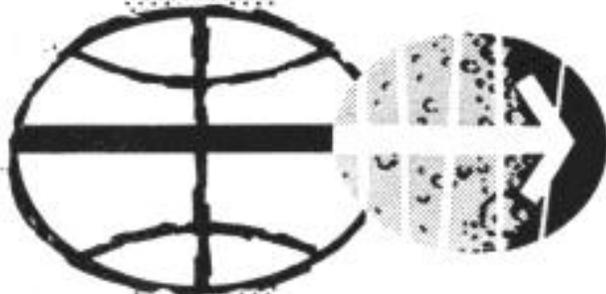


NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 15 MISSION REPORT

DISTRIBUTION AND REFERENCING

This paper is not suitable for general distribution or referencing. It may be referred only in other working correspondence and documents by participating organizations



MANNED SPACECRAFT CENTER  
HOUSTON, TEXAS

DECEMBER 1971

INDEXING DATA

DATE	CTR	#	T	PGM	SUBJECT	SIGNATOR	LOC
12-00 71	MSC	MSC-05161	R	AS	(copy)	MSC	051-5

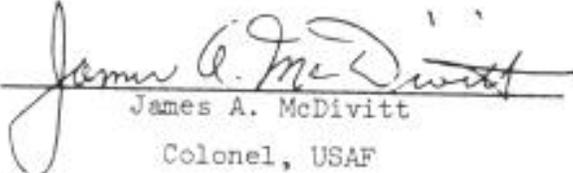
MSC-05161

APOLLO 15 MISSION REPORT

PREPARED BY

Mission Evaluation Team

APPROVED BY

  
James A. McDivitt

Colonel, USAF  
Manager, Apollo Spacecraft Program

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION  
MANNED SPACECRAFT CENTER  
HOUSTON, TEXAS  
December 1971

# TABLE OF CONTENTS

<b>1</b>	<b>MISSION SUMMARY</b>	<b>1</b>
<b>2</b>	<b>INTRODUCTION</b>	<b>5</b>
<b>3</b>	<b>TRAJECTORY</b>	<b>6</b>
<b>3.1</b>	<b>LAUNCH AND TRANSLUNAR TRAJECTORIES</b>	<b>6</b>
<b>3.2</b>	<b>LUNAR ORBIT</b>	<b>6</b>
3.2.1	Orbital Phase	6
3.2.2	Descent	11
3.2.3	Ascent and Rendezvous	12
3.2.4	Lunar Module Deorbit	13
3.2.5	Orbit-Shaping Maneuver and Subsatellite Launch	13
<b>3.3</b>	<b>TRANSEARTH AND ENTRY TRAJECTORY</b>	<b>13</b>
<b>4</b>	<b>LUNAR SURFACE SCIENCE</b>	<b>14</b>
<b>4.1</b>	<b>SUMMARY OF LUNAR SURFACE ACTIVITIES</b>	<b>14</b>
<b>4.2</b>	<b>APOLLO LUNAR SURFACE EXPERIMENTS PACKAGE CENTRAL STATION</b>	<b>19</b>
<b>4.3</b>	<b>PASSIVE SEISMIC EXPERIMENT</b>	<b>21</b>
<b>4.4</b>	<b>LUNAR SURFACE MAGNETOMETER EXPERIMENT</b>	<b>23</b>
<b>4.5</b>	<b>SOLAR WIND SPECTROMETER EXPERIMENT</b>	<b>24</b>
<b>4.6</b>	<b>HEAT FLOW EXPERIMENT</b>	<b>24</b>
<b>4.7</b>	<b>SUPRATHERMAL ION DETECTOR EXPERIMENT</b>	<b>25</b>
<b>4.8</b>	<b>COLD CATHODE GAGE EXPERIMENT</b>	<b>26</b>
<b>4.9</b>	<b>LASER RANGING RETRO-REFLECTOR EXPERIMENT</b>	<b>26</b>
<b>4.10</b>	<b>SOLAR WIND COMPOSITION EXPERIMENT</b>	<b>27</b>
<b>4.11</b>	<b>LUNAR SURFACE DRILL OPERATION</b>	<b>27</b>
<b>4.12</b>	<b>LUNAR GEOLOGY</b>	<b>27</b>
4.12.1	Landing Site	27
4.12.2	Extravehicular Traverses	28
4.12.3	Summary of Geology	30
4.12.4	Equipment	30
4.12.5	Photography	31
<b>4.13</b>	<b>SOIL MECHANICS EXPERIMENT</b>	<b>31</b>
<b>5</b>	<b>INFLIGHT SCIENCE AND PHOTOGRAPHY</b>	<b>33</b>
<b>5.1</b>	<b>GAMMA-RAY SPECTROMETER EXPERIMENT</b>	<b>36</b>
<b>5.2</b>	<b>X-RAY FLUORESCENCE EXPERIMENT</b>	<b>36</b>
<b>5.3</b>	<b>ALPHA-PARTICLE SPECTROMETER EXPERIMENT</b>	<b>37</b>
<b>5.4</b>	<b>MASS SPECTROMETER EXPERIMENT</b>	<b>37</b>
<b>5.5</b>	<b>PARTICLE SHADOWS /BOUNDARY LAYER EXPERIMENT</b>	<b>38</b>

<b>5.6</b>	<b>SUBSATELLITE MAGNETOMETER EXPERIMENT</b>	<b>38</b>
<b>5.7</b>	<b>S-BAND TRANSPONDER EXPERIMENT</b>	<b>39</b>
5.7.1	Command and Service Module/Lunar Module	39
5.7.2	Subsatellite	39
<b>5.8</b>	<b>DOWN-LINK BISTATIC RADAR OBSERVATIONS OF THE MOON</b>	<b>39</b>
<b>5.9</b>	<b>APOLLO WINDOW METEOROID EXPERIMENT</b>	<b>40</b>
<b>5.10</b>	<b>ULTRAVIOLET PHOTOGRAPHY - EARTH AND MOON</b>	<b>40</b>
<b>5.11</b>	<b>GEGENSCHNITT FROM LUNAR ORBIT</b>	<b>41</b>
<b>5.12</b>	<b>SERVICE MODULE ORBITAL PHOTOGRAPHY</b>	<b>42</b>
5.12.1	Panoramic Camera	42
5.12.2	Laser Altimeter	43
<b>5.13</b>	<b>COMMAND MODULE PHOTOGRAPHY</b>	<b>43</b>
<b>5.14</b>	<b>VISUAL OBSERVATIONS FROM LUNAR ORBIT</b>	<b>44</b>
<b>6</b>	<b><i>COMMAND AND SERVICE MODULE PERFORMANCE.</i></b>	<b>45</b>
<b>6.1</b>	<b>STRUCTURAL AND MECHANICAL SYSTEMS</b>	<b>45</b>
<b>6.2</b>	<b>ELECTRICAL POWER AND FUEL CELLS</b>	<b>45</b>
<b>6.3</b>	<b>CRYOGENIC STORAGE</b>	<b>45</b>
<b>6.4</b>	<b>COMMUNICATIONS</b>	<b>46</b>
<b>6.5</b>	<b>INSTRUMENTATION</b>	<b>46</b>
<b>6.6</b>	<b>GUIDANCE, NAVIGATION, AND CONTROL</b>	<b>46</b>
<b>6.7</b>	<b>PROPULSION</b>	<b>52</b>
6.7.1	Reaction Control Systems	52
6.7.2	Service Propulsion System	52
<b>6.8</b>	<b>ENVIRONMENTAL CONTROL AND CREW STATION</b>	<b>53</b>
6.8.1	Environmental Control System	53
6.8.2	Crew Station/Equipment	55
<b>6.9</b>	<b>CONTROLS AND DISPLAYS</b>	<b>55</b>
<b>6.10</b>	<b>EXTRAVEHICULAR ACTIVITY EQUIPMENT</b>	<b>56</b>
<b>6.11</b>	<b>CONSUMABLES</b>	<b>56</b>
6.11.1	Service Propulsion Propellant	56
6.11.2	Reaction Control System Propellant	58
6.11.3	Cryogenics	60
6.11.4	Water	61
<b>7</b>	<b><i>LUNAR MODULE PERFORMANCE</i></b>	<b>62</b>
<b>7.1</b>	<b>STRUCTURAL AND MECHANICAL SYSTEMS</b>	<b>62</b>
<b>7.2</b>	<b>COMMUNICATIONS</b>	<b>64</b>
<b>7.3</b>	<b>RADAR</b>	<b>65</b>
<b>7.4</b>	<b>CONTROLS AND DISPLAYS</b>	<b>65</b>
<b>7.5</b>	<b>GUIDANCE, NAVIGATION, AND CONTROL</b>	<b>66</b>
<b>7.6</b>	<b>PROPULSION</b>	<b>73</b>

7.6.1	Reaction Control System	73
7.6.2	Descent Propulsion System	73
7.6.3	Ascent Propulsion System	73
<b>7.7</b>	<b>ENVIRONMENTAL CONTROL SYSTEM</b>	<b>73</b>
<b>7.8</b>	<b>CONSUMABLES</b>	<b>74</b>
7.8.1	Descent Propulsion System Propellant	74
7.8.2	Ascent Propulsion System Propellant	75
7.8.3	Reaction Control System Propellant	76
7.8.4	Oxygen	77
7.8.5	Water	78
7.8.6	Electrical Power	79
<b>8</b>	<b>LUNAR SURFACE OPERATIONAL EQUIPMENT</b>	<b>79</b>
<b>8.1</b>	<b>EXTRAVEHICULAR MOBILITY UNIT</b>	<b>79</b>
<b>8.2</b>	<b>LUNAR ROVING VEHICLE</b>	<b>83</b>
8.2.1	Deployment	84
8.2.2	Steering	85
8.2.3	Electrical Power	85
8.2.4	Navigation	85
8.2.5	Thermal	86
8.2.6	Crew Station	86
8.2.7	EXTRAVEHICULAR COMMUNICATIONS EQUIPMENT	86
<b>9</b>	<b>PILOT'S REPORT</b>	<b>88</b>
<b>9.1</b>	<b>TRAINING</b>	<b>89</b>
<b>9.2</b>	<b>LAUNCH</b>	<b>89</b>
<b>9.3</b>	<b>EARTH ORBITAL OPERATIONS</b>	<b>89</b>
<b>9.4</b>	<b>TRANSLUNAR INJECTION</b>	<b>90</b>
<b>9.5</b>	<b>TRANSLUNAR FLIGHT OPERATIONS</b>	<b>90</b>
9.5.1	Transposition, Docking, and Extraction	90
9.5.2	Translunar Coast	91
9.5.3	Scientific Instrument Module Door Jettisoning	92
<b>9.6</b>	<b>LUNAR ORBIT OPERATIONS PRIOR TO DESCENT</b>	<b>92</b>
9.6.1	Lunar Orbit Insertion	92
9.6.2	Lunar Module Activation, Undocking and Separation	93
<b>9.7</b>	<b>POWERED DESCENT AND LANDING</b>	<b>93</b>
<b>9.8</b>	<b>LUNAR SURFACE OPERATIONS</b>	<b>95</b>
9.8.1	Lunar Module Cabin Activity	95
9.8.2	Lunar Geology	97
9.8.3	Lunar Surface Mobility Systems Performance	100
9.8.4	Lunar Surface Science Equipment Performance	105
<b>9.9</b>	<b>LUNAR ORBITAL SOLO OPERATIONS</b>	<b>106</b>
9.9.1	Maneuvers	106
9.9.2	Science and Photography	106
<b>9.10</b>	<b>ASCENT, RENDEZVOUS AND DOCKING</b>	<b>108</b>
9.10.1	Ascent	108
9.10.2	Rendezvous	109
9.10.3	Docking and Crew Transfer	110

<b>9.11</b>	<b>POST-DOCKING LUNAR ORBITAL OPERATIONS</b>	<b>110</b>
9.11.1	Lunar Module Jettison	110
9.11.2	Flight Plan Updating	111
9.11.3	Maneuvers	111
9.11.4	Command and Service Module Housekeeping	111
<b>9.12</b>	<b>TRANSEARTH FLIGHT OPERATIONS</b>	<b>112</b>
9.12.1	Tranearth Coast Extravehicular Activity	112
9.12.2	Science and Photography	113
9.12.3	Navigation	113
<b>9.13</b>	<b>ENTRY AND LANDING</b>	<b>114</b>
<b>10</b>	<b>BIOMEDICAL EVALUATION</b>	<b>139</b>
<b>10.1</b>	<b>BIOMEDICAL INSTRUMENTATION AND PHYSIOLOGICAL DATA</b>	<b>139</b>
<b>10.2</b>	<b>MEDICAL OBSERVATIONS</b>	<b>147</b>
10.2.1	Adaptation to Weightlessness	147
10.2.2	Medications	148
10.2.3	Sleep	148
10.2.4	Radiation	148
10.2.5	Visual Light Flash Phenomenon	149
10.2.6	Water	149
10.2.7	Food	150
<b>10.3</b>	<b>PHYSICAL EXAMINATIONS</b>	<b>150</b>
<b>10.4</b>	<b>BONE MINERAL MEASUREMENT</b>	<b>151</b>
<b>10.5</b>	<b>APOLLO TIME AND MOTION STUDY</b>	<b>152</b>
<b>11</b>	<b>MISSION SUPPORT PERFORMANCE</b>	<b>153</b>
<b>11.1</b>	<b>FLIGHT CONTROL</b>	<b>153</b>
<b>11.2</b>	<b>NETWORK</b>	<b>154</b>
<b>11.3</b>	<b>RECOVERY OPERATIONS</b>	<b>154</b>
11.3.1	Command Module Location and Retrieval	155
11.3.2	Postrecovery Inspection	158
<b>12</b>	<b>ASSESSMENT OF MISSION OBJECTIVES</b>	<b>159</b>
<b>13</b>	<b>LAUNCH PHASE SUMMARY</b>	<b>162</b>
<b>13.1</b>	<b>WEATHER CONDITIONS</b>	<b>162</b>
<b>13.2</b>	<b>ATMOSPHERIC ELECTRICITY</b>	<b>162</b>
<b>13.3</b>	<b>LAUNCH VEHICLE PERFORMANCE</b>	<b>163</b>
<b>14</b>	<b>ANOMALY SUMMARY</b>	<b>165</b>
<b>14.1</b>	<b>COMMAND AND SERVICE MODULES</b>	<b>165</b>
14.1.1	Service Module Reaction Control System Propellant Isolation Valves Closed	165
14.1.2	Water Panel Chlorine Injection Port Leakage	167
14.1.3	Service Propulsion System Thrust Light On Entry Monitor System	168
14.1.4	Integral Lighting Circuit Breaker Opened	171
14.1.5	Battery Relay Bus Measurement Anomaly	172
14.1.6	Mass Spectrometer Boom Talkback Indicated Half-Barberpole On Retract	173
14.1.7	Potable Water Tank Failure To Refill	177
14.1.8	Mission Timer Stopped	179
14.1.9	Main Parachute Collapse	180

14.1.10	Data Recorder Tape Deterioration	183
14.1.11	Digital Event Timer Obscured	185
14.1.12	Crew Restraint Harness Came Apart	187
14.1.13	Loose Object In Cabin Fans	189
14.1.14	Scanning Telescope Visibility	190
14.1.15	Gyro Display Coupler Roll Alignment	191
14.1.16	Unable To Open Circuit Breaker Supplying Main A Power To Battery Charger	193
14.1.17	Pivot Pin Failure On Main Oxygen Regulator Shutoff Valve	193
14.1.18	Crew Optical Alignment Sight Fell Off Stowage Mount	195
<b>14.2</b>	<b>LUNAR MODULE</b>	<b>196</b>
14.2.1	Water/Glycol Pump Differential Pressure Fluctuations	196
14.2.2	Water Separator Speed Decrease	198
14.2.3	Broken Water Gun/Bacteria Filter Quick Disconnect	199
14.2.4	Intermittent Steerable Antenna Operation	201
14.2.5	Descent Engine Control Assembly Circuit Breaker Open	204
14.2.6	Abort Guidance System Warning	204
14.2.7	No Crosspointer Indication	206
14.2.8	Broken Range/Range Rate Meter Window	208
<b>14.3</b>	<b>SCIENTIFIC INSTRUMENT MODULE EXPERIMENTS</b>	<b>210</b>
14.3.1	Panoramic Camera Velocity/Altitude Sensor Erratic	210
14.3.2	Loss of Laser Altimeter Altitude Data	213
14.3.3	Slow Deployment Of Mapping Camera	215
14.3.4	Gamma Ray Spectrometer Calibration Shifts	216
<b>14.4</b>	<b>APOLLO LUNAR SURFACE EXPERIMENTS PACKAGE AND ASSOCIATED LUNAR SURFACE EQUIPMENT</b>	<b>217</b>
14.4.1	Problems During The Lunar Surface Drilling Operations	217
14.4.2	Central Station Rear Curtain Retainer Removal Lanyard Broke	224
14.4.3	Intermittent Lock of Universal Handling Tool In Suprathermal Ion Detector Fitting	225
<b>14.5</b>	<b>GOVERNMENT FURNISHED EQUIPMENT</b>	<b>226</b>
14.5.1	Television Control Unit Clutch Slippage	226
14.5.2	Lunar Communications Relay Unit Downlink Signal Lost	227
14.5.3	Lunar Surface 16-mm Camera Magazines Jammed	230
14.5.4	Lunar Module Pilot's 70-mm Camera Film Advance Stopped	231
14.5.5	Difficult to Obtain Water From Insuit Drinking Device	232
14.5.6	Lunar Module Pilot Oxygen Purge System Antenna Was Damaged	232
14.5.7	Retractable Tether Failure	233
<b>14.6</b>	<b>LUNAR ROVING VEHICLE</b>	<b>235</b>
14.6.1	Deployment Saddle Difficult To Release From Vehicle	235
14.6.2	Volt/Ammeter Inoperative	236
14.6.3	Front steering System Inoperative	237
14.6.4	Lunar Roving Vehicle Seat Belt Problems	237
<b>15</b>	<b>CONCLUSIONS</b>	<b>238</b>

# 1 MISSION SUMMARY

Apollo 15 was the first in a series of missions designed to conduct exploration of the moon over longer periods, greater ranges, and with more instruments for scientific data acquisition than on previous missions. Major modifications and augmentations to the basic Apollo hardware were made, the most significant being installation of a scientific instrument module in one of the service module bays, modification of the lunar module to carry a greater scientific payload and permit a longer stay on the lunar surface, and the provision of a lunar roving vehicle. The landing site chosen for the mission was an area near the foot of the Apennine Mountains and adjacent to Hadley Rille. The mission accomplished all of its objectives and is providing the scientific community with a large amount of new information concerning the moon and its characteristics.

The space vehicle was launched from the Kennedy Space Center, Complex 39A at 9:34:00.6 a.m. e.d.t. (13:34:00.6 G.M.T.), on July 26, 1971. The spacecraft was manned by Colonel David R. Scott, Commander; Major Alfred J. Worden, Command Module Pilot; and Lt. Col. James B. Irwin, Lunar Module Pilot. The spacecraft /S-IVB combination was inserted into a nominal earth parking orbit approximately 1-1 minutes 44 seconds after lift-off. S-IVB restart for translunar injection was initiated during the second revolution at about 2 hours and 50 minutes. The maneuver placed the spacecraft/S-IVB combination on a translunar trajectory that would allow return to an acceptable earth-entry corridor using the reaction control system engines. Approximately 27 minutes after injection into the translunar trajectory, the command and service module was separated from the S-IVB and docked with the lunar module. The lunar module was extracted from the spacecraft/launch vehicle adapter. Shortly thereafter, the S-IVB tanks were vented and the auxiliary propulsion system was fired to target the S-IVB for a lunar impact. The first spacecraft midcourse correction was performed at about 28 hours 40 minutes with a velocity change of 5.3 ft/sec. One other small midcourse correction was performed during translunar flight.

The spacecraft was inserted into a lunar orbit of 170.1 by 57.7 miles at approximately 78 hours 32 minutes. About 1 hour later, the impact of the S-IVB stage was sensed by the Apollo 12 and 14 seismometers. The impact point was about 146 kilometers (79 miles) from the planned point and useful scientific data were obtained. The spacecraft was inserted into a 58.5-by-9.6 mile orbit at about 82 hours 40 minutes and a trim maneuver was performed later to adjust the perilune for powered descent. Undocking and separation occurred at about 100 hours 39 minutes and, approximately 1 hour later, the command and service module was placed in a near-circular orbit in preparation for the acquisition of scientific data.

The lunar module touched down on the lunar surface about 550 meters (1800 feet) from the planned target point at 104:42:29. The landing point was 26 degrees 6 minutes 4 seconds north latitude and 3 degrees 39 minutes 10 seconds east longitude (referenced to the Rima Hadley Lunar Photomap, Orbiter V site 26.1, First Edition, published by the U.S. Army Topographic Command, April 1970). A hover time capability of about 103 seconds remained after touchdown.

About 2 hours after landing, the Commander stood on the ascent engine cover with the upper part of his body extending through the upper hatch opening to photograph and describe the area surrounding the landing site. This extravehicular activity period lasted about 33 minutes. Approximately 12 1/2 hours later, the first lunar surface extravehicular activity commenced. Initially, the crew collected and stowed a contingency sample, deployed the lunar roving vehicle, unstowed the Apollo lunar surface experiments package and other equipment, and configured the lunar roving vehicle for lunar surface operations. Some problems were experienced in deploying and checking out the rover, but these were worked out and the crew drove the vehicle to Elbow Crater where they collected and documented samples, giving an enthusiastic and informative commentary on lunar features. Television control during various stops was provided by the Mission Control Center. After obtaining additional samples and photographs near St. George Crater, the crew returned to the lunar module using the lunar rover navigation system. The distance driven was about 10.3 kilometers (5.6 miles). The crew then proceeded to the selected Apollo lunar surface experiments package deployment site, approximately 110 meters (360 feet) west-northwest of the lunar module. They deployed the experiments essentially as planned except that the second heat flow experiment probe was not emplaced because drilling was more difficult than expected and the hole was not completed. The first extravehicular activity lasted about 6 hours and 33 minutes.

The crew spent about 16 hours in the cabin between the first and second extravehicular periods. Upon egress for the second extravehicular activity, the lunar rover was checked out and prepared for the second sortie. The first leg of the 12.5-kilometer (6.8-mile) round trip was south to the Apennine front, but east of the first traverse. Stops were made at Spur Crater and other points along the base of the front, as well as Dune Crater on the return trip. The return route closely followed the outbound route. Documented samples, a core sample, and a comprehensive sample were collected, and photographs were taken. After reaching the lunar module, the crew returned to the experiments package site where the Commander completed drilling the second hole for the heat flow experiment and emplaced the probe. During this period, the Lunar Module Pilot performed soil mechanics tasks. Drilling was again performed by the Commander to obtain a deep core sample, but the operation was terminated because of time constraints. The crew then returned to the lunar module and deployed the United States flag. The second extravehicular activity ended after about 7 hours 12 minutes.

The crew spent almost 14 hours in the cabin following the second extravehicular period. The third extravehicular activity began later than originally planned to allow additional time for crew rest. This and other delays at the experiments package site required deleting the planned trip to the North Complex. The first stop was at the experiments package site to retrieve the deep core sample. Two core sections were disengaged, but the drill and the remaining four sections could not be separated and were left for later retrieval. The third geological traverse was in a westerly direction and included stops at Scarp Crater, Rim Crater, and The Terrace, an area along the rim of Hadley Rille. Extensive samples were obtained as well as a double core tube and photographs of the west wall of Hadley Rille where exposed layering was observed. The return trip was east toward the lunar module with a stop at the experiments package site to retrieve the remaining sections of the deep core sample. One more section was separated and the

remaining three sections were returned in one piece. After returning to the lunar module, the lunar rover was unloaded and parked for ground-controlled television coverage of the lunar module ascent. The total distance traveled during the third extravehicular activity was about 5.1 kilometers (2.8 miles), and it lasted about 4 hours 50 minutes. The total distance traveled with the lunar roving vehicle during the three extravehicular periods was 27.9 kilometers (15.1 miles) and the total weight of lunar samples collected was about 170 pounds.

While the lunar module was on the surface, the Command Module Pilot completed 34 lunar orbits operating scientific instrument module experiments and cameras to obtain data concerning the lunar surface and the lunar environment. Some of the scientific tasks accomplished during this time were the photographing of the sunlit lunar surface; gathering data needed for mapping the bulk chemical composition of the lunar surface and determining the geometry of the moon along the ground track; visually surveying regions of the moon to assist in identification of processes which formed geologic features; obtaining lunar atmospheric data; and surveying gamma-ray and X-ray sources. Good-resolution panoramic and mapping camera photographs were obtained during the mission.

After 66 hours 54 minutes and 53 seconds on the lunar surface, the ascent stage lifted off at 171:37:23. A nominal lunar-module-active rendezvous was performed followed by docking at about 173 hours 36 minutes.

The lunar module was jettisoned one revolution later than planned because of some difficulty with verifying the tunnel sealing and suit integrity. Jettisoning occurred at about 179 hours 30 minutes and, about 1 1/2 hours later, the lunar module was deorbited with lunar impact occurring at 26 degrees 21 minutes north latitude and 0 degrees 15 minutes east longitude, about 23 1/2 kilometers (12.7 miles) from the planned impact point and about 93 kilometers (50 miles) west of the Apollo 15 landing site. The impact was recorded by the Apollo 12, 14, and 15 seismic stations.

Before leaving lunar orbit, a subsatellite was deployed in an orbit of approximately 76 by 55 miles, and all systems are operating as expected. The transearth injection maneuver was initiated at about 223 hours 49 minutes.

At about 242 hours, transearth coast extravehicular activity began. Television coverage was provided while the Command Module Pilot retrieved film cassettes and examined the scientific instrument module for abnormalities. This extravehicular activity lasted approximately 38 minutes. The total extravehicular time during the mission was 19 hours and 47 minutes.

A small midcourse correction of 5.6 ft/sec was performed at the seventh midcourse correction opportunity. The command module was separated from the service module as planned and a nominal entry followed with the spacecraft being observed on the main parachutes. During the descent, one of the three main parachutes failed, but a safe landing was made at 295:11:53. The best estimate of the landing coordinates is 26 degrees 7 minutes 48 seconds north latitude and 158 degrees 8 minutes 24 seconds west longitude, about 1 mile from the planned landing point. The crew was brought onboard the recovery ship by helicopter about 39 minutes after landing. The Apollo 15

mission was successfully concluded with the placing of the command module onboard the recovery ship about 1 1/2 hours after landing.

## 2 INTRODUCTION

The Apollo 15 mission was the fifteenth in the series using Apollo flight hardware and achieved the fourth manned lunar landing. The objectives of the mission were to investigate the lunar surface in a preselected area of the Hadley-Apennine region; emplace and activate surface experiments; evaluate the capability of the Apollo equipment to provide extended lunar surface stay time, increased extravehicular operations, and surface mobility; and conduct inflight experiments and photographic tasks from lunar orbit.

This report provides the National Aeronautics and Space Administration and other interested agencies with the results of the Apollo 15 mission. Some aspects of the mission such as preliminary scientific results and launch vehicle performance are reported in greater detail in other publications (references 1 and 2). This report contains:

A discussion of the performance of spacecraft systems and onboard equipment, including significant anomalies incurred and their resolution. (The results of anomaly investigations not completed by the time of publication will be reported individually.)

A description of the mission by the flight crew.

A summary of science operations.

A summary of the operational support provided by the flight control, manned space flight network, and recovery teams.

A biomedical evaluation.

A summary of launch conditions and launch vehicle performance.

An assessment of mission objectives satisfactorily accomplished.

In addition, in Appendixes A through D, the configuration of the spacecraft and the equipment aboard the spacecraft are identified, and information is presented concerning spacecraft manufacturing and checkout history, postflight testing, and data availability. A complete analysis of all applicable data is not possible within the time frame of the preparation of this report. Therefore, report supplements will be published as necessary. Appendix E lists the reports and gives their status, either published or in preparation.

Times, unless otherwise specified, are elapsed time from range zero, established as the integral second before lift-off. Range zero for this mission was 13:34:00 G.M.T., July 26, 1971. Customary units are used except in cases where metric units have a common usage, such as measurement of lunar surface distance. In these instances, both metric and customary units are given for convenience. All mileage distances are in nautical miles and all weights are referenced to earth gravity.

### **3 TRAJECTORY**

The general trajectory profile of this mission was similar to that of Apollo 14 except for a few refinements. The most significant difference was that the angle of descent to the lunar surface was increased from 14 degrees to 25 degrees. **Tables 3-I** and **3-II** give the times of major flight events and definitions of the events; **Tables 3-III** and **3-IV** contain trajectory parameter information; and **Table 3-V** is a summary of maneuver data.

#### **3.1 LAUNCH AND TRANSLUNAR TRAJECTORIES**

The launch trajectory is reported in reference 3. Because of earth parking orbit insertion dispersions, the S-IVB instrument unit received two navigation updates prior to translunar injection. Nominally, the translunar injection maneuver is targeted to a 79-mile pericyynthion. The command and service module, along with the lunar module, lower this pericynthion to 68 miles as a result of their ejection and separation from the S-IVB. Although the translunar injection maneuver was targeted to a 79-mile pericynthion, one of 139 miles was achieved. Two midcourse correction maneuvers were performed in addition to the normal vehicle separation maneuvers to reach the desired 68-mile pericynthion.

After command and service module/lunar module ejection, the S-IVB performed an evasive maneuver. Then the S-IVB, using its auxiliary propulsion system, performed two maneuvers designed to impact it at the desired lunar location of 3 degrees 39 minutes south latitude and 7 degrees 35 minutes west longitude. Initial tracking after the two maneuvers indicated that impact would be within 37 kilometers (20 miles) of the target. However, because of an error in targeting due to tolerances in the tracking vector and unexpected vehicle thrusting, the impact occurred 146 kilometers (79 miles) from the target at 1 degree 31 minutes south latitude and 11 degrees 49 minutes west longitude.

#### **3.2 LUNAR ORBIT**

##### **3.2.1 Orbital Phase**

The spacecraft was inserted into a 170.1-by-57.7-mile orbit around the moon using the service propulsion system. Approximately 4 hours later, the descent orbit insertion maneuver was performed, and the spacecraft was lowered to an orbit having a 58.5-mile apocynthion and a 9.6-mile pericynthion. This orbit gradually decayed, requiring a trim maneuver to adjust the orbit for powered descent initiation.

Event	Elapsed time, hr:min:sec.
Range zero - 13:34:00 G.m.t., July 26, 1971	
Lift-off - 13:34:00.6 G.m.t., July 26, 1971	
Earth orbit insertion	00:11:44
Translunar injection maneuver	02:50:03
S-IVB/Command and service module separation	03:22:27
Translunar docking	03:33:50
Spacecraft ejection	04:18:01
First midcourse correction/service propulsion system test	28:40:22
Second midcourse correction	73:31:15
Scientific instrument module door jettison	74:06:47
Lunar orbit insertion	78:31:47
S-IVB lunar impact	79:24:42
Descent orbit insertion	82:39:49
Descent orbit trim	95:56:45
Lunar module undocking and separation	100:39:16
Circularization maneuver	101:38:59
Powered descent initiation	104:30:09
Lunar landing	104:42:29
Start standup extravehicular activity	106:42:49
End standup extravehicular activity	107:15:56
Start first extravehicular activity	119:39:17
Data from Apollo lunar surface experiment package	125:18:00
End first extravehicular activity	126:11:59
Start second extravehicular activity	142:14:48
End second extravehicular activity	149:27:02
Start third extravehicular activity	163:18:14
Command and service module plane change	165:11:33
End third extravehicular activity	168:08:04
Lunar ascent	171:37:23
Terminal phase initiate	172:29:40
Terminal phase finalize	173:11:07
Docking	173:36:26
Lunar module jettison	179:30:01
Lunar module deorbit maneuver	181:04:20
Lunar module impact	181:29:37
Orbit shaping maneuver	221:20:48
Subsatellite launch	222:39:29
Transearth injection	223:48:46
Start transearth extravehicular activity	241:57:12
End transearth extravehicular activity	242:36:19
Third midcourse correction	291:56:50
Command module/service module separation	294:43:56
Entry interface	294:58:55
Begin blackout	295:59:13
End blackout	295:02:31
Forward heat shield jettison	295:06:45
Drogue deployment	295:06:46
Main parachute deployment	295:07:34
Landing	295:11:53

TABLE 3-I - SEQUENCE OF EVENTS

TABLE 3-II.- DEFINITION OF EVENT TIMES

<u>Event</u>	<u>Definition</u>
Range zero	Final integral second before lift-off
Lift-off	Time of instrumentation unit umbilical disconnect as indicated by launch vehicle telemetry
Earth orbit insertion	S-IVB engine cutoff time plus 10 seconds as indicated by launch vehicle telemetry
Translunar injection maneuver	Start tank discharge valve opening, allowing fuel to be pumped to the S-IVB engine
S-IVB/command module separation, translunar docking, spacecraft ejection, scientific instrument module door jettison, lunar module undocking and separation, docking, lunar module jettison, and subsatellite launch	The time of the event based on analysis of spacecraft rate and accelerometer data
Second midcourse correction, lunar orbit insertion, descent orbit insertion, circularization maneuver, powered descent initiation, plane change, lunar ascent, lunar module deorbit maneuver, shaping maneuver, and transearth injection	The time the spacecraft computer commanded the engine on as indicated in the computer word telemetry data
Service propulsion firing test/first midcourse correction, descent orbit insertion trim firing, and third midcourse correction	Engine ignition as indicated by the appropriate engine level telemetry measurement or other telemetry data
S-IVB lunar impact	The time of loss of S-band transponder signal
Lunar landing	The time of first contact of lunar module footpads with the lunar surface as derived from spacecraft rate data
Beginning of extravehicular activity	The time cabin pressure reaches 3 psia during depressurization as indicated by telemetry data
End of extravehicular activity	The time cabin pressure reaches 3 psia during repressurization as indicated by telemetry data
Apollo lunar surface experiment package first data	The receipt of first data considered valid from the Apollo lunar surface experiments package telemetry
Terminal phase initiate	The time of start of the terminal phase initiate maneuver during the rendezvous sequence as calculated by the computer
Terminal phase finalize	The time during the rendezvous sequence when the first braking maneuver is performed as determined from telemetry data
Lunar module impact	The time the final data point is transmitted from the lunar module telemetry system
Command module/service module separation	The time of separation by command module/service module separation relays via the telemetry system
Entry interface	The time the command module reaches 400 000 feet geodetic altitude as indicated by the best estimate of trajectory
Begin blackout	The time of S-band communication loss due to air ionization during entry
End blackout	The time of acquisition of S-band communications following blackout
Forward heat shield jettison, drogue deployment, and main parachute deployment	The time of deployment as indicated by the relay actuations via the telemetry system
Earth landing	The time the spacecraft was visually observed to touch the water

TABLE 3-II - DEFINITIONS OF EVENT TIMES

Missing Table

**TABLE 3-III - TRAJECTORY PARAMETERS**

TABLE 3-IV.- DEFINITION OF TRAJECTORY AND ORBITAL PARAMETERS

<u>Trajectory parameters</u>	<u>Definition</u>
Geodetic latitude	The spherical coordinate measured along a meridian on the earth from the equator to the point directly beneath the spacecraft, deg
Selenographic latitude	The definition is the same as that of the geodetic latitude except that the reference body is the moon rather than the earth, deg
Longitude	The spherical coordinate, as measured in the equatorial plane, between the plane of the reference body's prime meridian and the projected meridian to the spacecraft, deg
Altitude	The distance measured between the spacecraft and the reference radius of the earth along a line from the center of the earth to the spacecraft. When the reference body is the moon, it is the distance measured from the spacecraft along the local vertical to the surface of a sphere having a radius equal to the distance from the center of the moon to the landing site, ft or miles
Space-fixed velocity	Magnitude of the inertial velocity vector referenced to the body-centered, inertial reference coordinate system, ft/sec
Space-fixed flight-path angle	Flight-path angle measured positive upward from the body-centered local horizontal plane to the inertial velocity vector, deg
Space-fixed heading angle	Angle of the projection of the inertial velocity vector onto the body-centered local horizontal plane, measured positive eastward from north, deg

TABLE 3-IV - DEFINITION OF TRAJECTORY AND ORBITAL PARAMETERS

After lunar module separation, a circularization maneuver was performed placing the command and service module in a 65.2-by-54.8-mile orbit. The command and service

module remained in this orbit until about 6 hours prior to scheduled lunar module ascent when a 3-degree plane change maneuver was made so that the orbital plane of both vehicles would be coincident at the time of lift-off.

TABLE 3-V.- MANEUVER SUMMARY

(a) Translunar

Maneuver	System	Ignition time, hr:min:sec	Firing time, sec	Velocity change, ft/sec	Resultant perigee conditions				
					Altitude, miles	Velocity, ft/sec	Latitude, deg:min	Longitude, deg:min	Arrival time, hr:min:sec
Translunar injection	S-IVB	2:50:00.8	350.8	20 424.7	139	8222	23:05 E	173:15 E	78:31:23
First midcourse correction	Service propulsion	28:40:21.9	0.8	5.3	63	8279	23:26 E	171:52 E	78:35:15
Second midcourse correction	Service propulsion	73:11:14.8	0.9	5.4	68	8261	23:30 E	171:59 E	78:35:09

(b) Lunar orbit

Maneuver	System	Ignition time, hr:min:sec	Firing time, sec	Velocity change, ft/sec	Resultant orbit	
					Apoapsis, miles	Perigee, miles
Lunar orbit insertion	Service propulsion	75:31:46.7	398.4	3000.1	177.1	57.7
Descent orbit insertion	Service propulsion	82:39:49.1	24.5	213.9	58.5	9.6
Descent orbit insertion trim	Reaction control	95:56:44.7	18.9	3.2	60.3	8.8
Circularization	Service propulsion	101:38:59	3.7	68.3	65.2	54.8
Powered descent initiation	Lunar module descent propulsion	104:30:09.6	739.2	6813	-	-
Lunar orbit plane change	Service propulsion	165:11:32.7	18.3	330.6	64.5	53.6
Ascent	Lunar module ascent propulsion	173:37:23.2	431	6059	42.5	9.0
Terminal phase initiation	Lunar module ascent propulsion	175:29:40	2.6	72.7	64.4	18.7
Lunar module deorbit	Lunar module reaction control	181:04:19.8	83	300.3	-	-
Orbit shaping	Service propulsion	221:20:48	3.4	66.4	76.2	54.1

(c) Transearth

Event	System	Ignition time, hr:min:sec	Firing time, sec	Velocity change, ft/sec	Resultant entry interface conditions				
					Flight-path angle, deg	Velocity, ft/sec	Latitude, deg:min	Longitude, deg:min	Arrival time, hr:min:sec
Transearth injection	Service propulsion	223:48:45.8	141	3046.8	-7.13	36 087	13:26 N	175:42 W	294:37:45
Third midcourse correction	Service module reaction control	291:56:49.9	22.3	5.6	-6.49	39 096	14:13 N	175 W	294:56:55

TABLE 3-V - MANEUVER SUMMARY

### 3.2.2 Descent

A landing site update of 853 meters (2800 feet) downrange was incorporated at about 2 minutes into the powered descent to correct for downrange error. No other updates were necessary. The crew made at least seven site redesignations for a total change of 338 meters (1110 feet) uprange and 409 meters (1341 feet) to the right. The landing point was about 550 meters (1800 feet) northwest of the premission target point. The coordinates of the landing site are 26 degrees 6 minutes 4 seconds north latitude and 3

degrees 39 minutes 10 seconds east longitude, referenced to the Rima Hadley Lunar Photomap, Orbiter V site 26.1, First Edition, published by U.S. Army Topographic Command, April 1970 (**Fig. 3-1**)

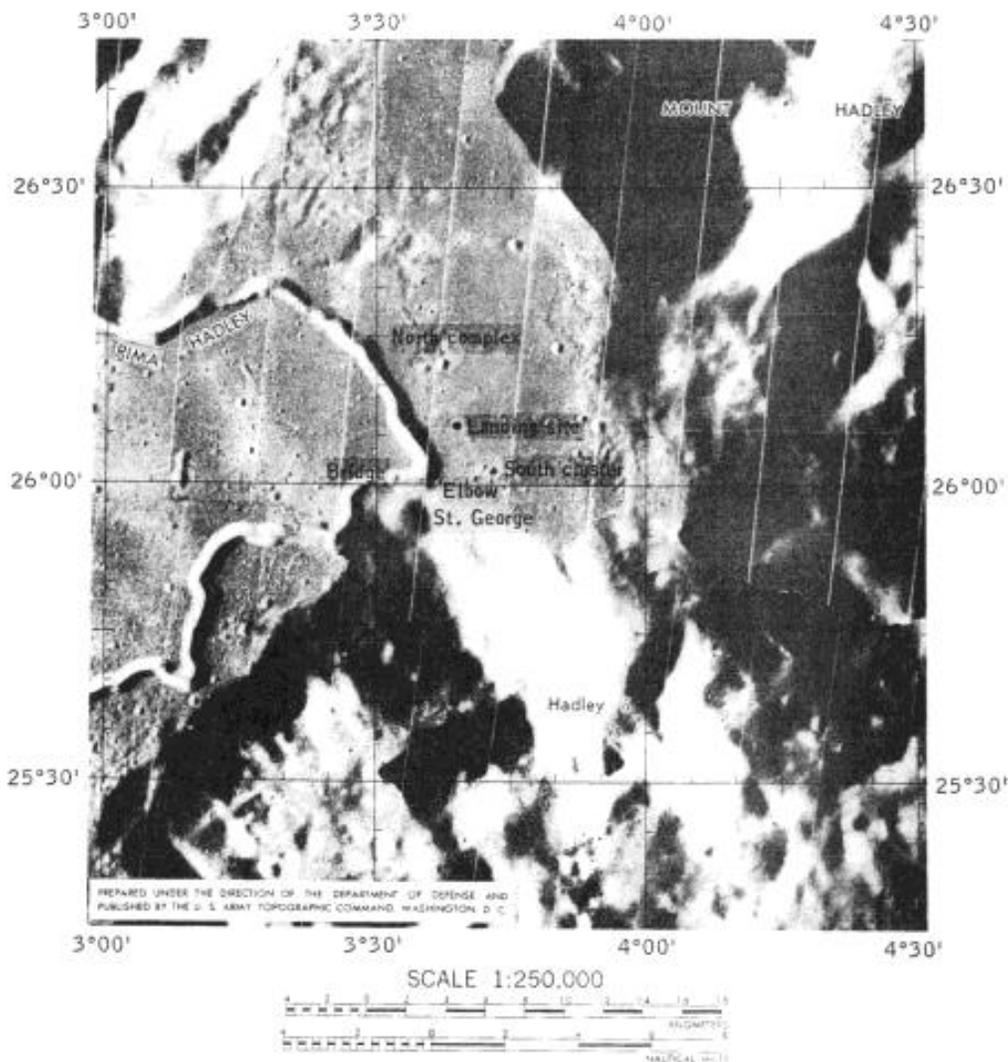


Figure 3-1.- Lunar module landing site on photomap of Hadley Plains.

### 3.2.3 Ascent and Rendezvous

The lunar module ascent occurred at 171:37:23 and the ascent stage was inserted into a 42.5-by-9.0-mile orbit. Some trimming of velocity residuals was required but, at insertion, the parameters were close to the desired values and a vernier adjustment maneuver was not required. The direct rendezvous technique, first used on Apollo 14, was executed nominally, and the lunar module and command and service module were haddocked about 1 hour 50 minutes after completion of the ascent maneuver.

### 3.2.4 Lunar Module Deorbit

Jettisoning of the lunar module ascent stage from the command and service module was delayed one revolution to permit reverifications of hatch and suit integrity. However, as a result of the delayed Jettisoning, the lunar module attitude for the maneuver was different than planned. With this change, the lunar module impacted the moon about 23.5 kilometers (12.7 miles) from the target. The coordinates of the impact point were 26 degrees 21 minutes north latitude and 0 degrees 15 minutes east longitude which is about 93 kilometers (50 miles) west of the Apollo 15 landing site.

The command and service module was to perform a 1-ft/sec retrograde separation maneuver after lunar module Jettisoning to minimize the possibility of recontact but, because of the Jettisoning delay, a 2-ft/sec posigrade maneuver was performed.

### 3.2.5 Orbit-Shaping Maneuver and Subsatellite Launch

In preparation for launching the subsatellite just prior to transearth injection, an orbit-shaping maneuver was performed during the 73rd lunar revolution using the service propulsion system to optimize the subsatellite orbit. The satellite was launched about an hour after the shaping maneuver into an orbit having an inclination of minus 28.7 degrees with an apocynthion of 76.3 miles and a pericynthion of 55.1 miles. The orbital lifetime is expected to be in excess of 1 year.

## **3.3 TRANSEARTH AND ENTRY TRAJECTORY**

The transearth injection maneuver was performed at 223 hours 49 minutes. On the transearth flight, no midcourse corrections were made until about 3 hours prior to entry. A 5.6-ft/sec maneuver was performed using the service module reaction control system. The service module was separated from the command module 15 minutes prior to entry. Conditions for the entry of the spacecraft into the earth's atmosphere were nominal. The best estimate of the spacecraft landing point is 26 degrees 7 minutes 48 seconds north latitude and 158 degrees 8 minutes 24 seconds west longitude.

## **4 LUNAR SURFACE SCIENCE**

The following experiments associated with the Apollo lunar surface experiment package are discussed in this section: suprathreshold ion detector, cold cathode gage, passive seismometer, lunar surface magnetometer, solar wind spectrometer, heat flow, and lunar dust detector. Other experiments and activities discussed consist of a laser ranging retro-reflector experiment, a solar wind composition experiment, lunar geology, soil mechanics, and lunar gravity measurement. Additionally, the operation of the lunar drill, used in conjunction with the heat flow experiment and to obtain a deep core sample, is described. A comprehensive discussion of the preliminary scientific results of this mission are contained in reference 2. References to descriptions of the experiment equipment are contained in Appendix A.

### **4.1 SUMMARY OF LUNAR SURFACE ACTIVITIES**

Because of the variety of surface features, the Haaley-Apennine landing site permitted extensive diversified geologic exploration and sampling. During the approximately 67 hours on the surface, the crew conducted a 33- minute standup extravehicular activity as well as three extravehicular activities for experiment operations and lunar roving vehicle traverses. The timelines for the three extravehicular activity periods are contained in Table 4-1. The actual and planned traverse routes are shown in figures 4.1 and 4-2, which are actual photographs of the lunar surface taken with the panoramic camera.

TABLE 4-I.- EXTRAVEHICULAR TRAVERSE EVENTS

Elapsed time, hr:min:sec	Event
First Extravehicular Activity	
<p>119:39:17 119:54:54 120:00:05 120:18:31 120:31:33 121:24:03 121:44:55 122:10:46</p> <p>122:22:36 122:34:44</p> <p>123:26:02 123:59:39</p> <p>126:11:59</p>	<p>Lunar module cabin depressurized. Television deployed. Contingency sample collected. Lunar roving vehicle offloaded. Lunar roving vehicle deployed. Lunar roving vehicle configured for traverse. Departed for station 1. Arrived at station 1. Performed radial sampling, gathered documented samples, and performed panoramic photography. Departed for station 2. Arrived at station 2. Gathered samples, obtained a double core tube sample and performed stereopanoramic and 500-mm photography. Departed for lunar module. Arrived at lunar module. Offloaded and deployed Apollo lunar surface experiment package, laser ranging retro-reflector, and solar wind composition experiment. Lunar module cabin repressurized.</p>
Second Extravehicular Activity	
<p>142:14:48 142:25:04 143:10:43 143:53:46</p> <p>144:58:49 145:01:11</p> <p>145:22:40 145:26:25</p> <p>146:16:09 146:28:59</p> <p>146:45:44 147:08:09</p>	<p>Lunar module cabin depressurized. Prepared equipment for lunar roving vehicle traverse. Departed for station 6. Arrived at station 6. Gathered samples, obtained a single core tube sample, obtained a special environmental sample from trench, and performed panoramic and 500-mm photography tasks. Departed for station 6a. Arrived at station 6a. Gathered samples and performed panoramic photography tasks. Departed for station 7. Arrived at station 7. Gathered selected samples, a comprehensive soil sample, and performed panoramic photography. Departed for station 4. Arrived at station 4. Gathered samples and performed panoramic photography. Departed for lunar module. Arrived at lunar module. Offloaded samples and configured lunar roving vehicle for trip to station 8 (Apollo lunar surface experiment package site).</p>

TABLE 4-I - EXTRAVEHICULAR TRAVERSE EVENTS

TABLE 4-I.- EXTRAVEHICULAR TRAVERSE EVENTS - Concluded

Elapsed time, hr:min:sec	Event
147:19:33 147:21:15	Departed for station 8. Arrived at station 8. Gathered comprehensive geologic sample, gathered special environmental sample from trench, drilled second heat flow hole and emplaced probe, drilled deep core sample hole, and performed penetrometer experiments.
148:31:08 148:32:17 149:27:02	Departed for lunar module. Arrived at lunar module. Deployed flag and began closeout. Lunar module cabin repressurized.
Third Extravehicular Activity	
163:18:14 164:04:13 164:09:00	Lunar module cabin depressurized. Departed for Apollo lunar surface experiment package site. Arrived at Apollo lunar surface experiment package site. Recovered deep core sample and performed photographic task of the lunar roving vehicle operation.
164:48:05 165:01:22	Departed for station 9. Arrived at station 9. Collected samples and performed panoramic photography tasks.
165:16:50 165:19:26	Departed for station 9a. Arrived at station 9a. Gathered extensive samples, obtained a double core tube and performed photographic tasks including 500-mm and stereoscopic panoramic photography.
166:14:25 166:16:45	Departed for station 10. Arrived at station 10. Gathered samples and performed 500-mm and panoramic photography tasks.
166:28:49 166:43:40	Departed for Apollo lunar surface experiment package site. Arrived at Apollo lunar surface experiment package site. Recovered drilled core sample and performed photographic tasks.
166:45:45 167:32:18	Arrived at lunar module. Began closeout procedures. Departed for final positioning of lunar roving vehicle to obtain television coverage of ascent.
167:35:24 168:08:04	Lunar roving vehicle positioned. Lunar module cabin repressurized.

TABLE 4-I - EXTRAVEHICULAR TRAVERSE EVENTS - Concluded

The outbound route of the first extravehicular traverse was southwest across the mare to the edge of Hadley Rille, south along the edge of the rille to Elbow Crater (station 1, Fig. 4-1); then along the edge of the rille to an area near St. George Crater (station 2). The return route was past Elbow Crater and directly across the mare to the lunar module. After returning to the lunar module, the crew deployed the Apollo lunar surface experiment package, the laser ranging retro-reflector, and the solar wind composition experiment (Fig. 4-3). The extravehicular activity was approximately 6 hours 33 minutes in duration and the traverse covered a distance of 10.3 kilometers (5.6 miles).

The second extravehicular activity was southeast across the mare to the Apennine front (stations 6 and 6a) northwest to Spur Crater (station 7) and north to the area of Dune Crater (station 4). The return was north across the mare to the Apollo lunar surface experiment package site (station 8) and then to the lunar module. The duration of the second extravehicular activity was approximately 7 hours 12 minutes, and the distance traveled was 12.5 kilometers (6.8 miles).

The third extravehicular activity included a 5.1-kilometer (2.8-mile) traverse. The outbound trip was west to Scarp Crater (stations 9 and 9a) and northwest along the edge of the rille (station 10). The return was east across the mare to the lunar module. The duration of the third extravehicular activity was approximately 4 hours and 50 minutes.

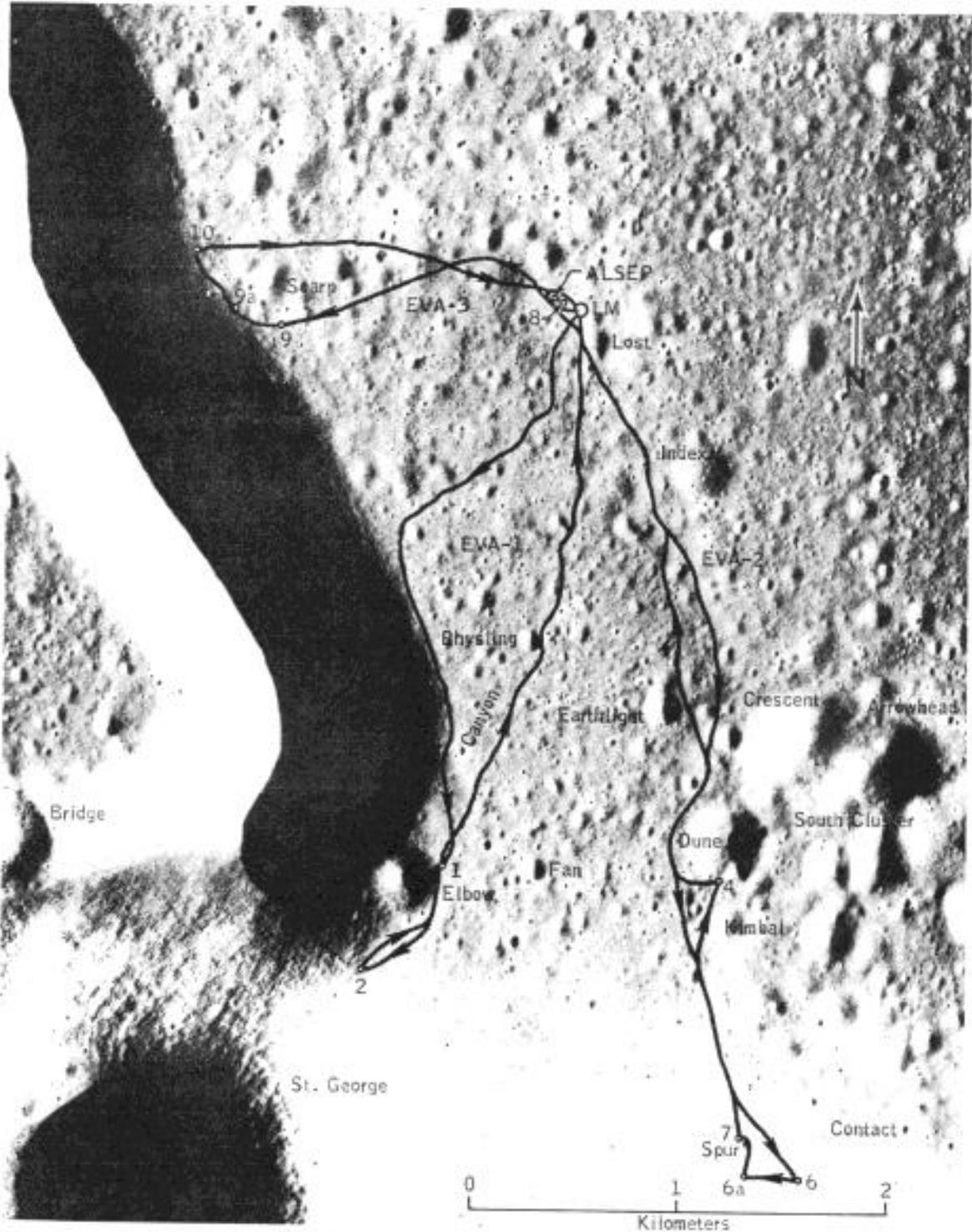


Figure 4-1.- Actual lunar surface traverse routes.

Figure 4-1.-Actual lunar surface traverse routes

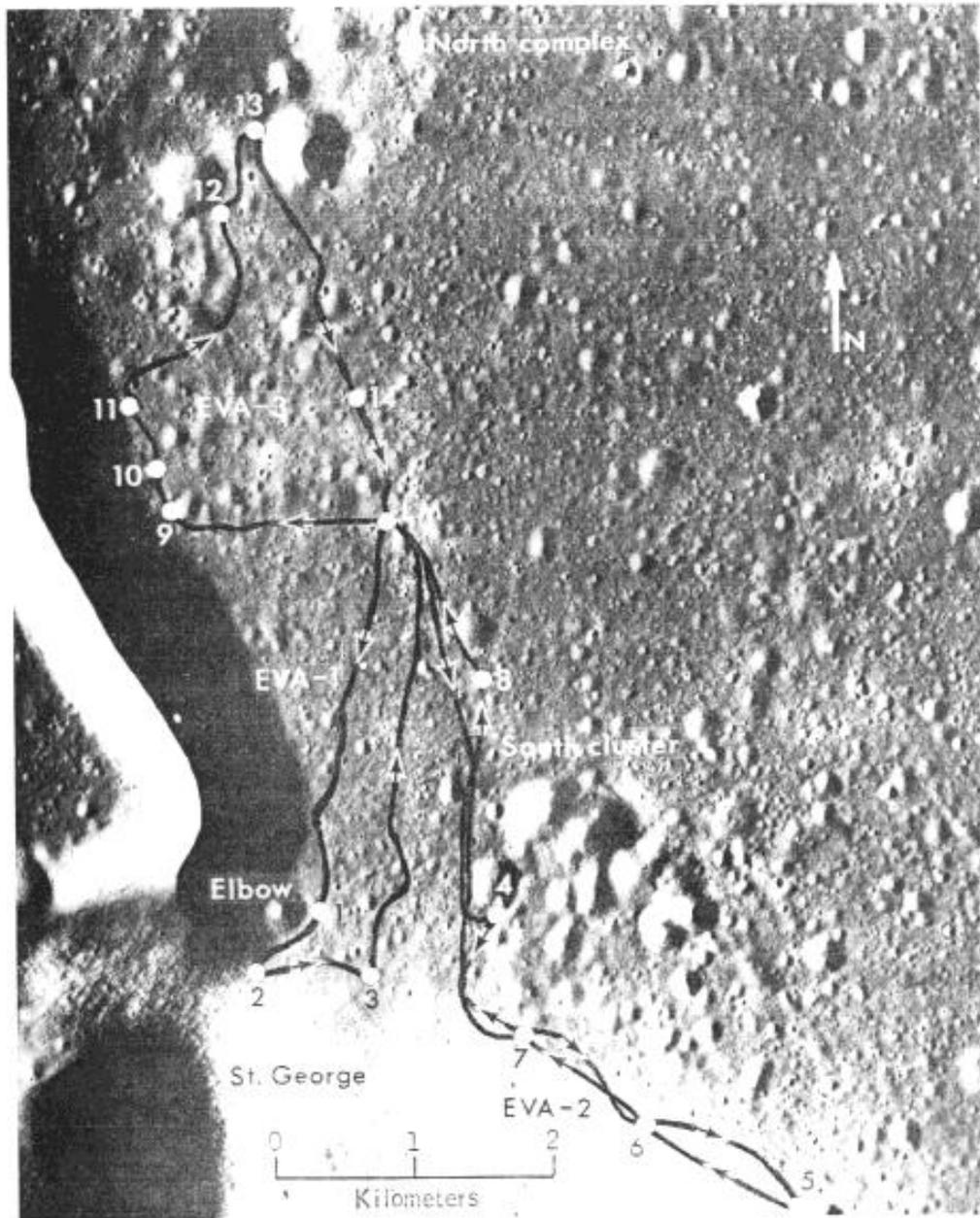


Figure 4-2.- Planned lunar surface traverse routes.

**Figure 4-2.-Planned lunar surface traverse routes.**

#### **4.2 APOLLO LUNAR SURFACE EXPERIMENTS PACKAGE CENTRAL STATION**

The site selected for emplacement of the central station was approximately 110 meters (360 feet) west-northwest of the lunar module. During erection of the central station, the rear-curtain-retainer removal lanyard broke, requiring the Lunar Module Pilot to remove the pins by hand. (See section 14.4.2 for further discussion.)

Initial acquisition of a downlink signal from the Apollo lunar surface experiment package was reported by the Canary Island station prior to antenna installation. Initial data were received in the Mission Control Center at 1850 G.M.T. (125:18:00) on July 31 and, within 1 hour, all instruments were turned on and operationally checked out. (The initial acquisition of data was earlier than expected because the shorting plug was inadvertently activated.) The radioisotope thermoelectric power source is providing 74.5 watts, the highest output of any Apollo lunar surface experiment package, and sufficient to operate the large complement of instruments. During the first lunar-night operation, the system reserve power registered as low as 1 watt. The solid-state timer, used for the first time on an Apollo lunar surface experiments package has generated all scheduled 18-hour pulses to initiate certain automatic functional changes.

Six days after startup, on August 6, the experiment package was subjected to its first lunar eclipse. This was a total eclipse and the package was closer to the center of the umbra than any previous Apollo lunar surface experiments package during any previous eclipse. During the eclipse, sun shield temperature of the central station dropped from plus 140 F to minus 143 F with accompanying rates of change of temperatures up to 260 F per hour. The central station engineering measurements provided data on the varying solar intensity throughout the eclipse. The instrument measured a lunar surface temperature change of 330 F during the eclipse. There was no indication of significant dust collection on the instrument's solar cells as a result of the lunar module ascent.

The system continues to exhibit normal performance. Equipment temperatures during both lunar day and lunar night are within design limits.

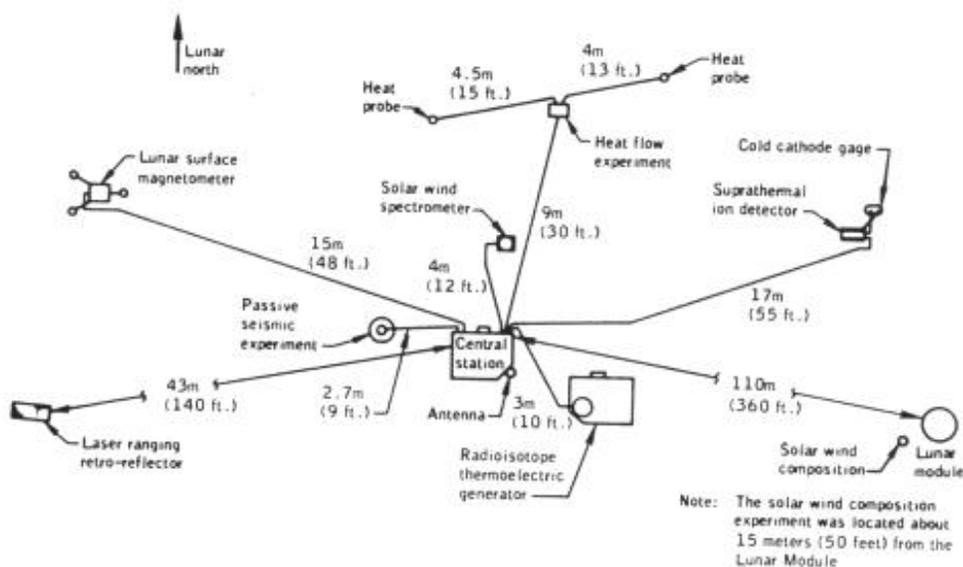


Figure 4-3.- Apollo lunar surface experiment deployment.

**Figure 4-3.-Apollo lunar surface experiment deployment**

### 4.3 PASSIVE SEISMIC EXPERIMENT

The passive seismic experiment was deployed approximately 2.7 meters (9 feet) west of the experiment package central station and has functioned well since its initial activation on July 31, 1971. One deviation from nominal operation has occurred. The instrument internal temperature fell below the predicted 126 F as the Apollo 15 site entered the first lunar night. This will not detrimentally affect the operation of the instrument except that degradation of gravity tidal data from the experiment is expected. Photographs of the instrument show the shroud skirt to be raised up at several places (fig. 4-4). Heat loss due to the uneven shroud accounts for the low night temperature.

4-8

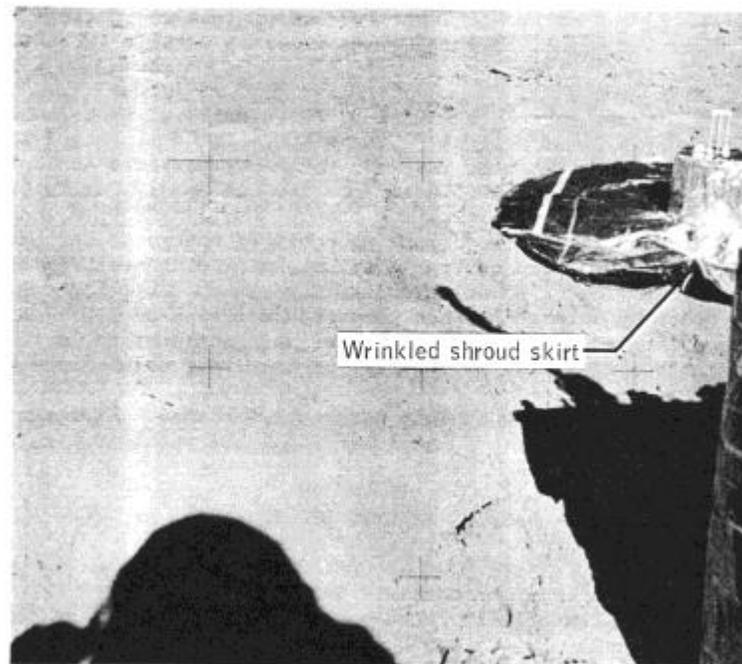


Figure 4-4.- Passive seismic experiment deployment.

#### Figure 4-4 - Passive seismic experiment deployment

The installation of this experiment at Hadley Rille provides a widely spaced network of seismic stations on the lunar surface which is essential for the location of natural lunar events. The first event to be recorded on all three Apollo Lunar surface experiment package stations was the impact of the lunar module ascent stage approximately 93 kilometers (50 miles) west of the Apollo 15 station. The signal generated by this impact spread slowly outward, reaching the Apollo 15 station in 28 seconds, and reaching the Apollo 12 and 14 stations, located to the southwest at distances of 1130 kilometers (610 miles) and 1049 kilometers (566 miles), respectively, in about 7 minutes (fig. 4-5). The

fact that this small source of energy was detected at such great range strongly supports the hypothesis that meteoroid impacts are being detected from the entire lunar surface.

Two moonquakes were detected at all three stations during the moon's travel through its first perigee following activation of the Apollo 15 station. Preliminary analysis places the focus of one of these moonquakes 400 kilometers (216 miles) southwest of the Apollo 15 station. It is believed that the second moonquake was 1000 kilometers (540 miles) southwest of the Apollo 12 and 14 stations and was 800 kilometers (432 miles) deep.

The S-IVB impact extended the depth to which lunar structure can be determined by seismic methods to nearly 100 kilometers (54 miles). From this and previous data from impacts of spent vehicles, it now appears that a change in composition occurs at a depth of 25 kilometers (13.5 miles) beneath the surface. This implies that the lunar crust is equivalent to the crust of the earth, and about the same thickness.

Two meteoroid impacts were recorded at the Apollo 15 station during the first 2 weeks of its operation. One of these impacts was recorded at all three stations and was located by triangulation. Fourteen impact events were recorded by the Apollo 12 and 14 stations during this period. Signals were also recorded that were caused by events and activities associated with lunar surface operations, particularly the movements of the lunar roving vehicle and the ascent from the lunar surface. The lunar roving vehicle was detected at ranges up to 5 kilometers (2-7 miles) with an accuracy within approximately 0.5 kilometer (0.27 mile). As in previous missions, numerous signals were also recorded from venting of gases and thermal "popping" within the lunar module.

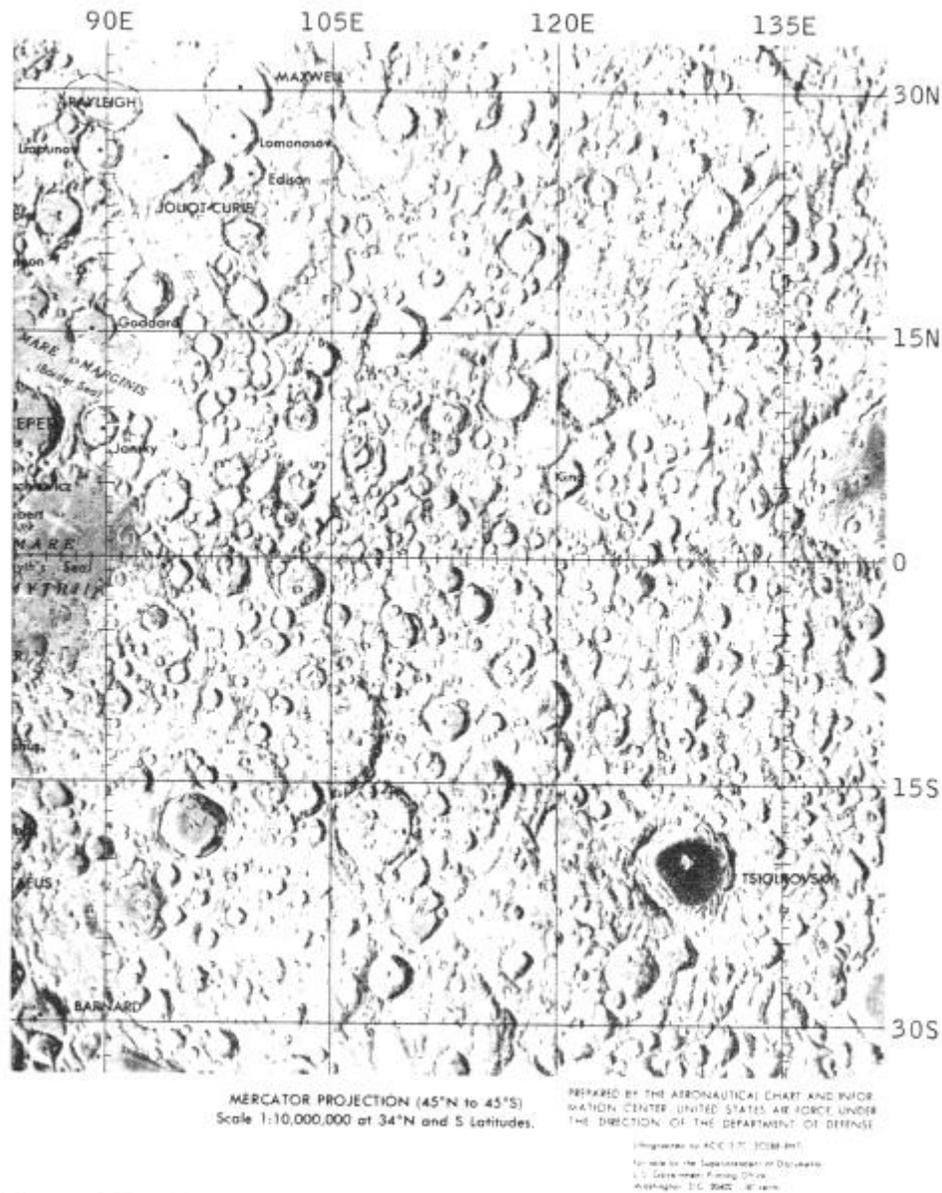


Figure 4-5.- Apollo landing sites and impact locations on the lunar surface.

**Figure 4-5 - Apollo landing sites and impact locations on the lunar surface**

#### **4.4 LUNAR SURFACE MAGNETOMETER EXPERIMENT**

The lunar surface magnetometer was deployed approximately 15 meters (48 feet) west-northwest of the Apollo lunar surface experiment package central station. The experiment was initially commanded on near the end of the first extravehicular activity. A-11 operations of the experiment have been nominal. The electronics temperature has reached a high of 157 F at lunar noon, and a low of 41 F during lunar night. The

instrument is routinely commanded into a calibration mode every 18 hours by the central station timer. The one-time site survey was successfully-completed on August 6. The remanent magnetic field at the site is lower than that measured at the Apollo 12 and 14 sites. The eddy current produced by the interaction of the solar wind with the lunar surface has been measured.

#### **4.5 SOLAR WIND SPECTROMETER EXPERIMENT**

The solar wind spectrometer was deployed 4 meters (13 feet) north of the Apollo lunar surface experiment package central station and was activated near the end of the first extravehicular activity. The instrument recorded engineering and background data for approximately 2 earth days before the seven dust covers were removed.

The instrument recorded normal magnetospheric plasma data until the instrument passed into the geomagnetic tail of the earth. As expected, the plasma level in the geomagnetic tail was below the measurement threshold of the instrument (and essentially no solar wind plasma was detected) Upon emerging from the geomagnetic tail, the instrument was switched to the extended-range mode with no operational problems. The instrument will be left in this mode for correlation of data with the Apollo 12 solar wind spectrometer which is also operating in the same mode. A comparison of samples of simultaneous data from the two instruments has already demonstrated differences in the electron and proton components of the solar wind plasma that strikes the surface of the moon at the two stations. The solar plasma levels during the lunar night, as expected, were below the measurement threshold of the instrument.

#### **4.6 HEAT FLOW EXPERIMENT**

Deployment of the heat flow experiment was started on the first extravehicular activity and completed on the second extravehicular activity. A minor problem was experienced in removing two Boyd bolts that fasten the heat flow experiment components to the subpallet and problems were encountered in drilling the holes for two probes and emplacing the second probe. Refer to sections 4.11 and 14.4.1 for further discussion. The electronics box was placed about 9 meters (30 feet) north-northeast of the central station. The first probe hole was drilled about 4 meters (12 feet) east of the electronics box and the second, about 4.5 meters (15 feet) west of the box. The first hole was drilled to a depth of about 172 centimeters (70 inches) and probe 1 was emplaced during the first extravehicular activity, but the drilling of the second hole and emplacement of probe 2 was deferred because of time constraints. Drilling was resumed at the second hole during the second extravehicular activity and a hole depth of about 172 centimeters (70 inches) was again achieved; however, damage to a bore stem section (sec. 14.4.1) prevented probe 2 from reaching the bottom of the hole. The first heat flow experiment probe extends from a point 47 centimeters (19 inches) below the surface to a point 152 centimeters (62 inches) below the surface. Because of the damage to the bore stem in the other hole, the second probe extends from the surface to 105 centimeters (43 inches) below the surface (see **Fig. 4-6**).

The experiment was turned on at 1947 G.m.t., July 31, and valid temperature data were received from all sensors. Because of the shallow emplacement of probe 2, high near-

surface temperature gradients will keep the differential thermometers on the upper section off-scale during most of a lunar day-night cycle. The lower section of probe 2 and both the upper and lower sections of probe 1 are returning valid data on subsurface temperatures. Sensors on these sections that are shallower than 80 centimeters (32 inches) are seeing the effects of the diurnal cycle of surface temperature, but these variations are well within the range of measurement. Lunar surface temperatures are being obtained from five of the eight thermocouples in the probe cables that are just above or on the lunar surface because of the shallow emplacement.

Data for the reference thermometer sampled with the probe 2 thermocouple measurement went off-scale high at 1027 G.m.t - , August 7; however, the data from this reference thermometer is also sampled with the probe 1 thermocouple measurement, and is valid. Therefore, no data have been lost.

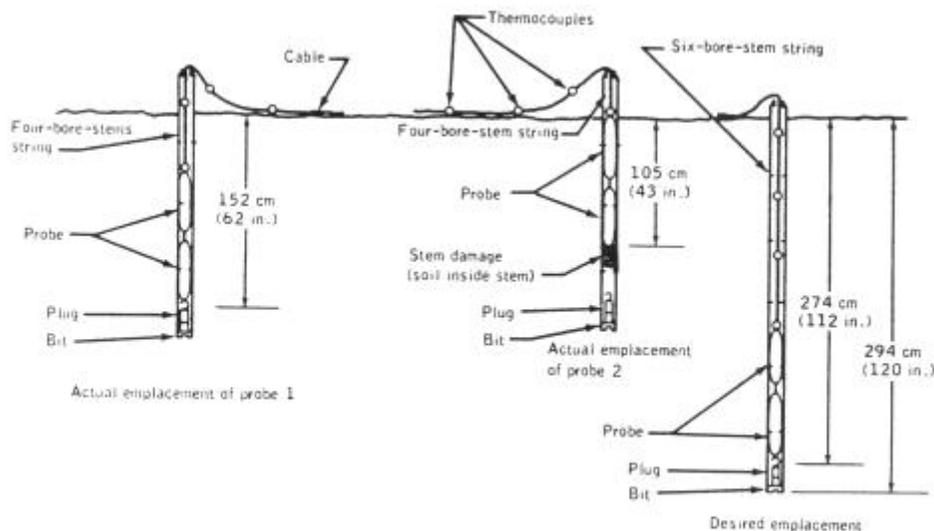


Figure 4-6.- Heat flow experiment bore-stem and probe emplacement.

#### 4.7 SUPRATHERMAL ION DETECTOR EXPERIMENT

The suprathemal ion detector experiment was deployed and aligned approximately 17 meters (55 feet) east-northeast of the Apollo lunar surface experiment package central station. Some difficulty was encountered during deployment when the universal handling tool did not properly interface with the experiment receptacle and, as a result, the instrument was dropped. The instrument was initially turned on near the end of the first extravehicular activity and operated normally, returning good scientific data. After about 30 minutes of operation the instrument was commanded to "standby" to allow outgassing. The dust cover was removed by ground command prior to the second extravehicular activity. Subsequently, the instrument was commanded on for five periods of approximately 30 minutes each to observe the effects of: (1) depressurization for the second extravehicular activity, (2) depressurization for the third extravehicular

activity, (3) depressurization for equipment jettisoning, (4) ascent, and (5) lunar module ascent stage impact. During some of this time simultaneous observations of intense magnetosheath ion fluxes were made by all three suprathreshold ion detector instruments now on the moon. The high voltage was commanded off prior to the hotter part of the first lunar day to allow further outgassing and was commanded back on shortly before lunar sunset.

#### **4.8 COLD CATHODE GAGE EXPERIMENT**

The cold cathode gage experiment was deployed about 0.3 meter (1 foot) northeast of the suprathreshold ion detector experiment. The instrument was turned on and the seal was commanded open 3 minutes prior to the end of the first extravehicular activity. Upon initial turn-on, the gage indicated full-scale, and during the first half hour, the output became slightly less than full-scale. Subsequently, the high voltage was commanded off to allow outgassing.

The experiment was operated five more times simultaneously with the suprathreshold ion detector experiment for periods of approximately 30 minutes each. The purpose of the operations was to observe the effects of the lunar module depressurizations for the second and third extravehicular activities and equipment jettison, the effects of the lunar module ascent from the lunar surface, and lunar module ascent stage impact. In each of the three depressurizations, the output of the experiment was driven to full-scale for approximately 30 seconds. The response to the lunar module depressurizations was very similar to that obtained during the Apollo 14 mission. The lunar module ascent resulted in the longest full-scale output (approximately 85 seconds). The exhaust from the lunar module ascent was detected for approximately 17 minutes.

The high voltage was turned off until just prior to the first lunar sunset to permit additional instrument outgassing. As the instrument and the lunar surface cooled during lunar night, the output of the gage gradually decreased to  $10E-12$  torr. This value is very near that observed on the Apollo 14 gage during lunar night. Two gas clouds of unknown origin were observed at the Apollo 15 site at 0400 and 1930 G.m.t. on August 15; these may be associated with Apollo 15 hardware left on the lunar surface.

#### **4.9 LASER RANGING RETRO-REFLECTOR EXPERIMENT**

The laser ranging retro-reflector was deployed during the first extravehicular activity approximately 43 meters (140 feet) west-southwest of the Apollo lunar surface experiment package central station. Leveling and alignment were accomplished with no difficulty. The McDonald Observatory team initially acquired a return signal from the Apollo 15 instrument August 3, 1971, when atmospheric conditions first permitted ranging. Based on successful acquisition on every attempt, and the receipt of four to five consecutive returns during a number of operations, the return signal strength appears higher than returns from the Apollo 11 and 14 retroreflectors (fig. 4-5). No degradation of the retro-reflector appears to have resulted from lunar module ascent engine firing.

#### **4.10 SOLAR WIND COMPOSITION EXPERIMENT**

The solar wind composition experiment, a specially prepared aluminum foil designed to entrap noble gas particles, was deployed at the end of the first extravehicular period and retrieved near the end of the third extravehicular period. The experiment was deployed approximately 15 meters (50 feet) southwest of the lunar module for a total foil exposure time of 41 hours and 8 minutes. Upon retrieval, the foil could not readily be rolled up mechanically and had to be rolled manually. This problem has been experienced on previous missions but does not affect the experiment. The returned hardware showed that the edge of the foil had rolled onto the reel-handle, which caused enough friction to stop the mechanical wind-up. Good data on the abundance of the isotopes of helium and neon in the solar wind have already been obtained.

#### **4.11 LUNAR SURFACE DRILL OPERATION**

The lunar surface drill, used for the first time on the lunar surface, provided a means for one crewman to emplace the heat flow experiment probes below the lunar surface and collect a subsurface core. For the heat flow experiment, the bore stems used in drilling remained in position in the lunar soil and functioned as an encasement to preclude cave-in of unconsolidated material. The subsurface core was obtained by drilling six core stems into the lunar soil. The stems were then removed and capped for return to earth.

The performance of the drill power-head and the core stem was good. However, full depth penetration with the bore stems was a problem and extraction of the core stems from the hole was difficult (see sec. 14.4.1). The two bore stem holes were drilled to a depth of about 172 centimeters (70 inches) instead of the desired 294 centimeters (120 inches), with one of the bore stem strings probably sustaining damage at a point slightly above the first joint [about 105 centimeters (43 inches) below the surface] (see fig. 4-6).

#### **4.12 LUNAR GEOLOGY**

##### **4.12.1 Landing Site**

The lunar module landed on an undulating cratered plain adjacent to the high and steep-sloped Apennine Mountains (**Fig. 4-7**). Most of the craters in the vicinity of the landing site are subdued and are rimless or have low raised rims. Rock fragments and boulders are abundant along the rim of Hadley Rille and around a few of the fresher craters.

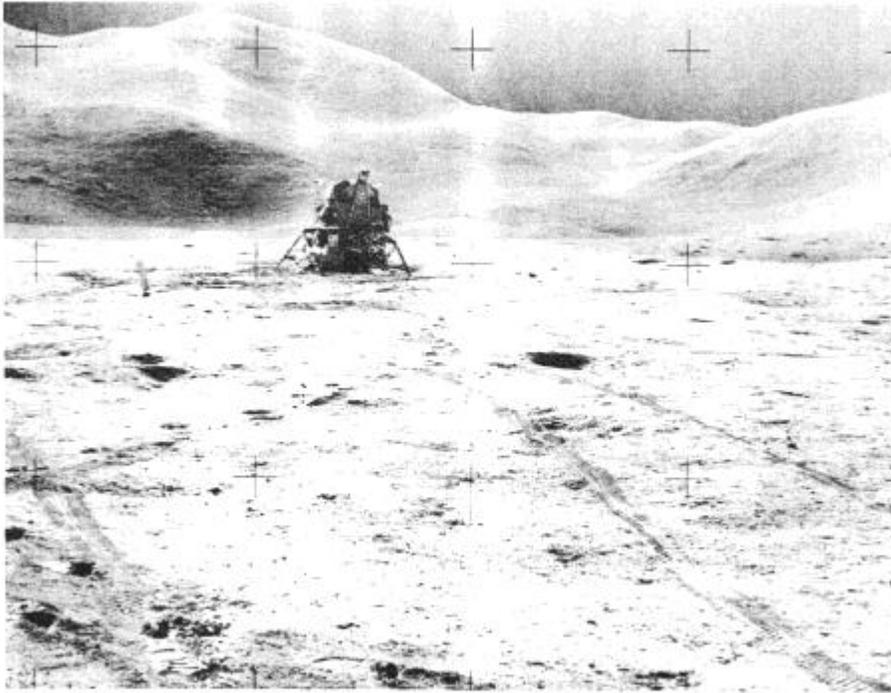


Figure 4-7.- Lunar module on Hadley Plain.

#### 4.12.2 Extravehicular Traverses

Areas visited during the extravehicular activities that are defined on photogeologic maps were the mare surface of Palus Putredinis; the Apennine Mountain Front; Hadley Rille; and a cluster of secondary craters.

The standup extravehicular activity provided the geologic and terrain setting for later traverse updating, and allowed the crew to familiarize themselves with landmarks. Good photographs were obtained of the landing site and the Hadley Delta area by using the 60-mm and 500-mm focal-length lenses. **Figure 4-8** is typical of the photographs obtained.

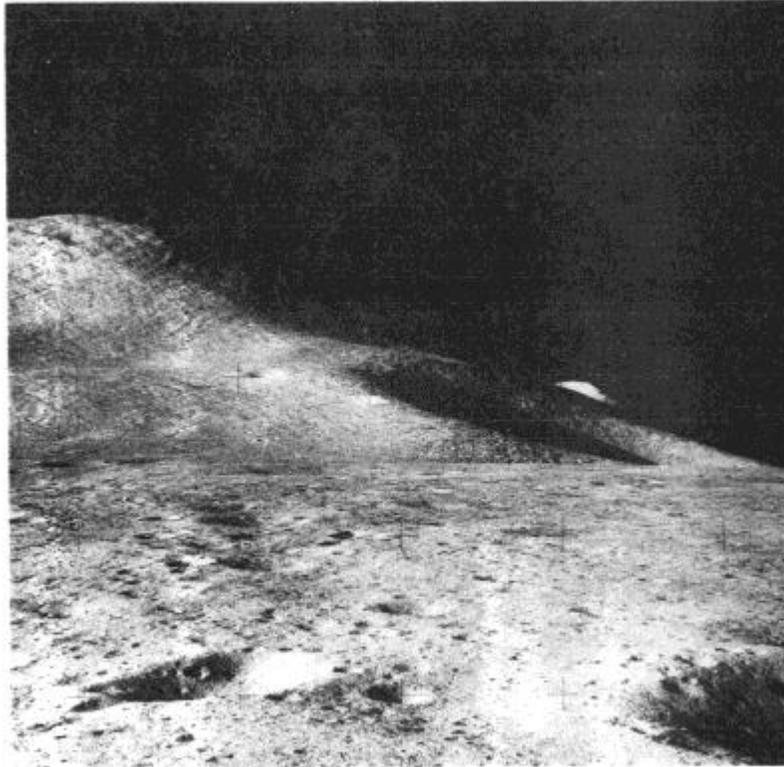


Figure 4-8.- Mount Hadley Delta and St. George Crater.

On the first extravehicular traverse, station 1 and 2 tasks were performed as planned. Refer to figures 4-1 and 4-2 for locations of stations on actual and planned traverse routes. The radial sample was collected at Elbow crater (station 1). Documented samples and a comprehensive sample, including a double-core, were collected near St. George crater (station 2). Station 3 on the planned traverse was not visited because of time constraints.

The traverse time allowed during the second extravehicular activity was shortened because of the time required to complete the Apollo lunar surface experiment package site tasks that were not completed during the first extravehicular activity. Therefore, the planned traverse to the east along the front was shortened and only three stations along the front, 6, 6a, and 7 (Spur Crater), were visited. Several documented samples were collected at stations 6 and 6a, and a single core was collected at station 6. Documented samples and a comprehensive sample were collected at station 7. The planned stop at station 4 (Dune crater) was accomplished on the return from the front.

The start of the third extravehicular activity was delayed and, as a result, was shortened from 6 to 4 1/2 hours. The shortening of the extravehicular period, plus the time required to remove the deep core sample from its hole, required that the traverse to the North

Complex and mare station 14 be omitted. However, the premission-planned traverse to stations 9 and 10 at Hadley Rille was made. A sample was collected from the upper portion of a bedrock ledge exposed near station 9a. Documented samples were collected at stations 9 and 9a, and a rake sample and a double core were collected at station 9a.

#### 4.12.3 Summary of Geology

Samples were collected that appear to be representative of the Apennine Front, the mare in the vicinity of the landing site, bedrock from the rim of Hadley Rille, and a possible ray associated with Aristillus or Autolycus. Some breccias were collected that appear similar to those collected on Apollo 14; others appear to be indurated regolith. Abundant glass, found as coatings on the rock surfaces and in fractures, is associated with the breccias. Also collected were basaltic rocks ranging from vesicular and scoriaceous to dense with phenocrysts greater than a centimeter long.

Layered bedrock ledges are exposed in the upper parts of Hadley Rille. These are probably a cross-section of mare flows and possibly bedded pyroclastic materials. At least some of the samples from station 9a (Fig. 4-1) are probably representative of the upper part of the mare stratigraphic sequence.

Planar structures in the Apennine Front occur in different orientations from one mountain to the next, which suggests rotation of large blocks along the faults that are shown on the premission maps. The faults and associated rotation were probably caused by the impact event that produced the Imbrium Basin.

#### 4.12.4 Equipment

The equipment used during the geology portion of the extravehicular activities performed well with the following exceptions:

Excessive time was required for the gnomon to damp.

Sample return container 2 did not seal properly because part of a collection bag was caught in the seal area between the knife edge and the indium seal.

The Lunar Module Pilot's camera did not advance film properly near the end of the second extravehicular activity. The camera failed again during the third extravehicular activity after six pictures had been taken. (See section 14-5.4 for further discussion.)

Problems with the drilling were experienced as described in section 14.4.1.

The polarizing filter for the Hasselblad electric data camera could not be installed because of excessive dust in the bayonet fitting.

Both retractable tethers (Yo-yo's) failed (sec. 14.5.7).

The tongs were difficult to operate during the third extravehicular activity; however, a backup pair was supplied for such a contingency and these operated satisfactorily.

#### 4.12.5 Photography

A total of 1152 photographs was taken on the lunar surface with the 60- mm and 500- mm focal-length cameras. At least one 360-degree 60-mm panorama was taken at every station except stations 3 and 4. Apollo 15 was the first mission using the 500-mm focal length lens mounted on the 70-mm Hasselblad electric data camera hand-held by a crewman. Good photography was obtained of distant photographic targets such as the Apennine Front and across and inside Hadley Rille.

#### **4.13 SOIL MECHANICS EXPERIMENT**

The soil mechanics experiment provided data on the physical characteristics and Mechanical properties of the lunar surface and subsurface soil. Activities during Apollo 15 unique to the soil mechanics experiment were performed during a compressed timeline at station 8 (Fig. 4-1) near the end of the second extravehicular activity with only one crewmember available to do the work instead of two as scheduled. The Lunar Module Pilot excavated the soil mechanics trench, exposing a Vertical face to an estimated depth of a little more than 1 foot without apparent difficulty. The vertical face exposed a fine-grained, cohesive, gray material with small white fragments and larger fragments of glass. Stratification was not observed. Digging of the trench was followed by six of seven planned measurements using the self- recording penetrometer. These tests consisted of four cone penetration resistance tests and two plate load tests. No time was available for the detailed planned photographic documentation of these activities, nor was the television camera on the lunar roving vehicle in a suitable position to provide a high degree of detail.

Data from the penetrometer tests were intended to provide quantitative information on the physical properties of the lunar soil to depths up to 74 centimeters (30 inches). The data, now under study, will probably not provide the quantitative detail on physical properties originally anticipated because of the following reasons: (1) The soil structure at the site had greater penetration resistance than had been anticipated (2) A particularly resistant layer was encountered at a depth of only a few centimeters; (3) The lunar surface plate on the penetrometer failed to stay in the proper position during four of the tests because the friction between the reference plate bushing and the shaft was less than had been anticipated.

The average depth of lunar roving vehicle tracks was on the order of 1 centimeter (1/2 inch), in agreement with predictions based on terrestrial wheel/soil interaction tests performed on simulated lunar soil. **Figure 4-9** illustrates vehicle tracks, footprints, and excavated areas.



Figure 4-9.- Lunar roving vehicle tracks and crewman's footprints with excavated areas in the foreground.

The large number of photographs and the numerous observations made by the crew concerning the interactions between the lunar surface and (1) the crew, (2) the lunar module, (3) the lunar roving vehicle, and (4) the experiment packages and handtools will be of value to the soil mechanics experiment. The core tubes, which were modified for this mission, performed satisfactorily.

#### **4.14 LUNAR GRAVITY MEASUREMENT**

Accelerometer data telemetered to earth between lunar module touchdown and inertial measurement unit powerdown were obtained to determine the observed lunar gravity. Nineteen measurements were taken during four operating periods. The time spans and sequence of the periods were: 658 seconds, 240 seconds, 12 seconds, and 269 seconds. Lunar gravity at the landing site will be calculated from the reduced data.